DATA EVALUATION RECORD

PC Code 128931/100094 **Dicamba, DGA, and BAPMA Salts**

Reference: Robinson, A.P., D.M. Simpson, W.G. Johnson. 2013. Response of Glyphosate-Tolerant Soybean Yield Components to Dicamba Exposure. Weed Science 61:526–536

Test material: Clarity (Reg No. 7969-137);
Common name: Dicamba

Study classification: Supplemental

Primary Reviewer:	Frank T. Farruggia, Ph.D. EPA Reviewer	2018.10.31 14:20:30 -04'00' Date
Secondary Reviewer:	EDWARD ODENKIRCHEN Ed Odenkirchen, Ph.D. EPA Reviewer	Digitally signed by EDWARD ODENKIRCHEN Date: 2018.10.31 14:32:21 -04'00' Date

Reviewer Conclusions:

This study evaluated the impact of dicamba on soybean, measuring plant height, multiple measures of plant reproduction impacts including yield, as well as the magnitude of plant visual signs of injury corresponding to these measures. While there are significant and toxicologically relevant effects reported for these measures, this review focuses on the estimated endpoints for grain yield (Table 6) and the relationships established between plant yield and percent plant injury (Figure 5).

5% Grain Yield Reduction
V2 Exposure = 0.142 g ae/ha
V5 Exposure = 0.528 g ae/ha
R2 Exposure = 0.242 g ae/ha

Other measures of yield and reproductive effects had reported ED_{05} estimates ranging from 0.020 to 10.3 g a.e./ha.

A significant relationship between yield and injury were established in the study. As described in the report and shown in Figure 5, the relative relationship of % injury to yield changes depending on the growth stage of exposure with nearly a 1:1 relationship established at early growth stages (e.g., V2) and more of a 2:1 relationship at later vegetative and early reproductive stages (e.g., V5 & R2).

Summarized from Study Report: Materials and Methods

"Field experiments were planted at the Throckmorton Purdue Agriculture Center (TPAC) located near Lafayette, IN (40.3001, 286.9056), on May 18, 2009, and on June 8, 2010 and at the Dow AgroSciences Midwest Research Center (MRC) located near Fowler, IN (40.6336, 286.1101), on June 6, 2009. The 2010 field experiment at MRC was flooded and data were not collected. Soil type at TPAC in 2009 was an Octagon silt loam (fine-loamy, mixed, active, mesic Mollic Oxyaquic Hapludalfs); at TPAC in 2010 soil was a Throckmorton silt loam (fine-silty, mixed, superactive, mesic Mollic Oxyaquic Hapludalfs), and soil type at MRC in 2009 was a Darroch silt loam (fine-loamy, mixed, superactive, mesic Aquic Argiudolls). Beck's brand '342NRR' soybean was seeded in 38-cm rows at 430,000 seeds/ha. All fertility practices were conducted according to Purdue University recommendations (Gerber et al. 2012). Conventional tillage was utilized at all field sites, except at TPAC in 2009 where no tillage was used.

Plots were kept weed-free by applying PRE and POST herbicides and by subsequent hand-weeding as required. Weed control at TPAC during both years consisted of metribuzin (158 g ai/ha) plus chlorimuron (26 g ai/ha) applied just prior to soybean emergence. POST weed control at TPAC in 2009 consisted of glyphosate (1,060 g ae/ha) plus ammonium sulfate (2,037 g/100 L), applied on June 19; at TPAC in 2010, glyphosate (1,120 g/ha) plus ammonium sulfate (2,037 g/100 L) plus clethodim (102 g ae/ha) were applied on July 11. Clethodim was used to control glyphosate-tolerant volunteer maize. At the MRC location in 2009, trifluralin (1,400 g ae/ha) plus imazethapyr (70 g ae/ha) were incorporated twice prior to planting. Detailed information of herbicides utilized can be found in Table 1.

The experimental design was a randomized complete block with a factorial arrangement of treatments. Treatments were application timing at V2, V5, or R2 stages of soybean and dicamba (diglycolamine salt) rates of 0, 0.06, 0.2, 0.6, 1.1, 2.3, 4.5, 9.1, and 22.7 g/ha. Soybean plants within a plot were considered to have reached a certain stage of development when at least half of the plants reached that stage (Fehr and Caviness 1977). Plot size was 3.1 m wide and 9.1 m long and consisted of a 3.1-m-long and 1.5-m-wide buffer to reduce the possibility of off-target movement into adjacent plots.

All dicamba treatments were applied in 140 L/ha carrier volume using a CO_2-pressurized backpack sprayer with a 3.1- m-wide boom and XR11002 flat fan nozzles (TeeJet Spraying Systems Company, Wheaton, IL 60189) at 138 kPa. Wind speeds were less than 5 km/h when treatments were applied. Visual estimates of percentage of soybean injury were recorded 14 and 28 DAT using a scale of 0 to 100%, where 0 5 no crop injury and 100 5 complete plant death (Table 2; Figure 1). Plant height was recorded from three arbitrarily selected plants at the R8 growth stage. At maturity, 10 plants from the middle two rows of each treatment were arbitrarily selected to determine the following yield components as outlined by Board and Modali (2005): seed mass (g/100 seeds), seeds/m, seeds/pod, pods/m, main-stem reproductive nodes/m, pods reproductive/node, mainstem nodes/m, and percentage of reproductive nodes. Plots were harvested with a plot combine and seed yield was adjusted to 130 g/kg moisture. Oil and protein concentrations were determined from machine-harvested seed using near-infrared reflectance spectroscopy at the Purdue University Grain Quality Laboratory.

Statistical approaches described in detail within the report.

Summary of Relevant Information from Author's Results and Discussion

Results and Discussion

Environmental conditions varied by location and year. Higher temperature and lower precipitation were attributed to lower seed yields at the TPAC location in 2009 than at other sites and years. Average soybean yield in the untreated checks at TPAC in 2009 was 2.2 mg/ha as compared to 4.4 mg/ha at TPAC in 2010 and MRC in 2009.

Nonlinear regressions were fit to describe soybean injury according to the ANOVA (Table 4). At 28 DAT the ED_{20} values ranged from 0.359 to 1.37 g/ha dicamba (Table 5). The author reported that apical meristem death occurred at rates greater than or equal to 2.3 g/ha, with regrowth typically occurring at axillary buds either at the cotyledonary node or the unifoliate node, causing the growth of two main branches, with one branch generally becoming dominant. They considered this a possible explanation for why soybean plants treated with dicamba can have a delayed progression through growth stages compared to untreated plants.

Table 4. Analysis of variance of soybean injury, seed yield and plant height, yield components, and seed composition treated with different rates of dicamba ranging from 0 to 22.7 g ha^{-1} at the V2, V5, and R2 soybean growth stages at the Throckmorton Purdue Agricultural Center, Lafayette, IN in 2009 and 2010 and at the Midwest Research Center, near Fowler, IN in 2009.

Source	Experiment	Dicamba rate	Treatment timing	Dicamba rate × treatment timing
	P value			
Soybean injury				
14 DAT[a]	0.5780	< 0.0001	< 0.0001	0.2316
28 DAT	0.0017	< 0.0001	< 0.0001	< 0.0001
Seed yield and plant height				
Seed yield	0.0219	< 0.0001	0.0389	0.0009
Plant height	0.2429	< 0.0001	< 0.0001	0.0008
Yield components				
Seeds m^{-2}	0.0069	< 0.0001	0.0593	0.0002
Seed mass	0.6660	0.0160	< 0.0001	< 0.0001
Pods m^{-2}	0.0117	< 0.0001	0.3264	0.0024
Seeds pod^{-1}	0.6760	< 0.0001	0.0004	0.0001
Main stem reproductive nodes m^{-2}	0.5177	< 0.0001	0.0140	< 0.0001
Pods reproductive $node^{-1}$	0.0517	< 0.0001	< 0.0001	< 0.0001
% Reproductive nodes	0.0860	0.0006	0.0066	0.0041
Main stem nodes m^{-2}	0.7036	< 0.0001	0.0040	< 0.0001
Seed composition				
Oil concentration	0.1274	< 0.0001	< 0.0001	< 0.0001
Protein concentration	0.1738	< 0.0001	< 0.0001	< 0.0001

[a] Abbreviation: DAT, days after treatment.

Table 5. Nonlinear curve regression parameters of visual estimates of soybean injury at 14 and 28 d after treatment used in dicamba treatments applied to soybean at the V2, V5, or R2 growth stages at the Throckmorton Purdue Agricultural Center, Lafayette, IN, in 2009 and 2010 and at the Midwest Research Center, near Fowler, IN, in 2009.

		Regression parameters[c]					
DAT[a]	Growth stage[b]	b	d	e	$ED_{10} \pm SE$[d]	$ED_{20} \pm SE$	$ED_{50} \pm SE$
					g ae ha^{-1}		
14	V2, V5	−0.465	85.2	1.05	0.203 ± 0.02	0.676 ± 0.09	4.05 ± 1.2
14	R2	−0.520	72.9	1.07	0.285 ± 0.03	0.937 ± 0.2	6.97 ± 3.6
MRC in 2009 and TPAC 2009							
28	V2	−0.344	125	3.50	0.238 ± 0.04	0.884 ± 0.3	4.55 ± 3.0
28	V5	−0.654	84.7	0.540	0.169 ± 0.02	0.399 ± 0.04	1.44 ± 0.3
28	R2	−0.609	75.7	0.424	0.134 ± 0.02	0.359 ± 0.04	1.80 ± 0.5
TPAC in 2010							
28	V2	−0.822	55.8	1.05	0.544 ± 0.05	1.37 ± 0.2	15.6 ± 7.8
28	V5	−0.472	80.2	0.904	0.192 ± 0.02	0.653 ± 0.1	4.41 ± 2.0
28	R2	−0.584	76.9	1.25	0.368 ± 0.03	1.02 ± 0.2	5.30 ± 1.8

[a] Abbreviations: DAT, days after treatment; ED, effective dose, MRC, Midwest Research Center; TPAC, Throckmorton Purdue Agricultural Center.
[b] Treatments of dicamba were applied at the MRC in 2009 and at the TPAC in 2009 and 2010.
[c] Dose-response parameters where b represents the relative slope of the curve, d the upper limit, and e the inflection point of the equation $Y = d(\exp[-\exp\{b(\log x - e)\}])$.
[d] ED_{10}, ED_{20}, ED_{50}, effective dose causing 10, 20, and 50% visual soybean injury.

Yield Effects.

Nonlinear regressions were fit to describe soybean seed yield according to the ANOVA (Table 4). The ED_{10} for seed yield at TPAC in 2009 was 0.169 g ae/ha (Table 6) and at MRC in 2009 and TPAC in 2010 ranged from 0.529 to 1.1 g a.e./ha. "Similar to the results at MRC in 2009 and TPAC in 2010, other researchers reported that dicamba treatments of 5.6 g/h at V1 to V3 soybean stages caused less seed yield loss when compared to dicamba applications at V7 to early bloom (Auch and Arnold 1978; Kelley et al. 2005)." "The greater yield reduction at TPAC in 2009 is likely the result of less precipitation, which minimized the ability of the soybean plant to compensate for the early season injury.

Nonlinear regressions were fit to describe each yield component according to the analysis of variance (Table 4). Treatment timing and rate affected the response of most yield components. The number of seeds/m, pods/m, seeds/pod, reproductive nodes/m, and nodes/m were reduced as dicamba rates increased, but generally had less change than yield (Table 6).

Implications of Visual Injury Estimates on Seed Yield Loss.

Regression analyses of estimated visual soybean injury were correlated to seed yield loss. Visual estimates of soybean injury at 14 and 28 DAT were pooled because they were not different from each other ($P < 0.1739$). The V2 treatment timing was different from the V5 treatment timing ($P < 0.0015$) and the R2 treatment timing ($P < 0.0014$), whereas the V5 treatment timing and the R2 treatment timing were not different ($P < 0.5527$) (data not shown). Predicting yield loss from visual soybean injury ratings was significant at the V2 treatment timing ($P < 0.0001$) and the V5 and R2 treatment timings ($P < 0.0001$) (Figure 5). The V2 treatment timings had an $r^2 = 0.92$ and the V5 and R2 treatment timings had an $r^2 = 50.91$.

Table 6. Nonlinear regression parameters of seed yield, plant height, and yield components as affected by dicamba treatments applied to soybean at the V2, V5, or R2 growth stages at the Throckmorton Purdue Agricultural Center (TPAC), Lafayette, IN, in 2009 and 2010 and at the Midwest Research Center (MRC), near Fowler, IN, in 2009.

Component	Growth stage[a]	Regression parameters[b]					
		b	*d*	*e*	$ED_5 \pm SE$[c]	$ED_{10} \pm SE$	$ED_{20} \pm SE$
					g ae ha^{-1}		
MRC in 2009, TPAC in 2010							
Seed yield	V2	0.549	14.5	1.22	0.142 ± 0.2	0.73 ± 0.8	----
	V5	1.00	45.5	7.19	0.528 ± 0.3	1.10 ± 0.4	2.38 ± 0.7
	R2	0.901	60.0	15.6	0.242 ± 0.2	0.539 ± 0.3	1.17 ± 0.7
TPAC 2009							
	V2, V5, R2	0.520	111	15.9	0.042 ± 0.05	0.169 ± 0.1	0.706 ± 0.7
Plant height	V2	1.43	25.5	3.61	1.24 ± 0.6	2.21 ± 0.5	4.87 ± 1.9
	V5	0.747	50.8	4.39	0.211 ± 0.09	0.577 ± 0.2	1.74 ± 0.5
	R2	0.911	44.0	5.37	0.526 ± 0.2	1.21 ± 0.3	3.10 ± 0.7
MRC in 2009, TPAC in 2010							
Seeds m^{-2}	V2	0.175	79.4	1,166,500	0.186 ± 3	11.9 ± 166	----
	V5	1.30	41.0	7.77	1.62 ± 0.04	2.92 ± 0.05	5.71 ± 0.1
	R2	1.06	58.6	10.9	1.10 ± 0.4	2.22 ± 0.7	4.74 ± 1.9
TPAC 2009							
	V2,V5,R2	0.369	318	690	0.009 ± 0.06	0.061 ± 0.4	0.416 ± 2.9
Seed mass	V2	−8.61	1.38	5.63	----	----	----
	V5	5.12	5.19	0.289	0.365 ± 0.6	----	----
	R2	2.32	−8.88	4.05	----	----	----
MRC in 2009, TPAC in 2010							
Pods m^{-2}	V2	0.110	16.3	212	0.025 ± 0.6	----	----
	V5	1.45	31.1	7.04	2.11 ± 1.0	3.65 ± 1.2	7.17 ± 2.7
	R2	1.01	46.5	9.98	1.15 ± 0.5	2.44 ± 1.1	5.64 ± 3.2
TPAC 2009							
	V2,V5,R2	0.377	417	1,718	0.014 ± 0.04	0.089 ± 0.3	0.577 ± 1.8
Seeds pod^{-1}	V2	−1.36	4.25	1.64	----	----	----
	V5	−0.570	15.6	3.41	2.72 ± 12	14.2 ± 117	----
	R2	−0.460	43.3	16.8	3.16 ± 3.1	7.35 ± 11	----
Reproductive nodes m^{-2}	V2	−0.313	104	13.6	0.073 ± 0.09	0.347 ± 0.3	1.28 ± 2.3
	V5	−1.69	73.1	2.16	1.21 ± 0.4	1.44 ± 0.3	1.86 ± 0.3
	R2	−0.384	173	20.1	0.748 ± 0.4	1.32 ± 1.0	2.72 ± 3.2
Pods reproductive $node^{-1}$	V2	2.55	−33.0	6.11	----	----	----
	V5	4.26	−64.0	3.68	----	----	----
	R2	2.10	−36.8	8.20	----	----	----
Nodes m^{-2}	V2	0.340	106	146	0.020 ± 0.07	0.162 ± 0.6	1.45 ± 5
	V5	1.83	69.1	3.49	0.847 ± 0.3	1.27 ± 0.4	1.94 ± 0.4
	R2	1.27	62.8	8.15	1.14 ± 0.6	2.04 ± 0.8	3.82 ± 1
Percent reproductive nodes	V2	14.3	−2.45	0.995	----	----	----
	V5	−14.2	3.77	1.32	----	----	----
	R2	−0.454	223	195	10.3 ± 16	16.1 ± 29	----

[a] Treatments of dicamba were applied at the Midwest Research Center (MRC) in 2009 and at the Throckmorton Purdue Agriculture Center (TPAC) in 2009 and 2010.

[b] Dose response parameters where *b* represents the relative slope of the curve, *d* the upper limit, and *e* the inflection point of the equation. The equation $Y = d(\exp[-\exp\{b(\log x - e)\}])$ described seeds pod^{-1}, main-stem reproductive nodes m^{-2}, and percentage of reproductive nodes; the equation $Y = d(1 - \exp[-\exp\{b(\log x - \log e)\}])$ was fit to soybean seed yield, plant height, seeds m^{-2}, seed mass, pods m^{-2}, seeds pod^{-1}, pods reproductive $node^{-1}$, and main-stem nodes m^{-2}.

[c] Abbreviation: ED_5, ED_{10} ED_{20}, effective dose, causing 5, 10, or 20% loss.

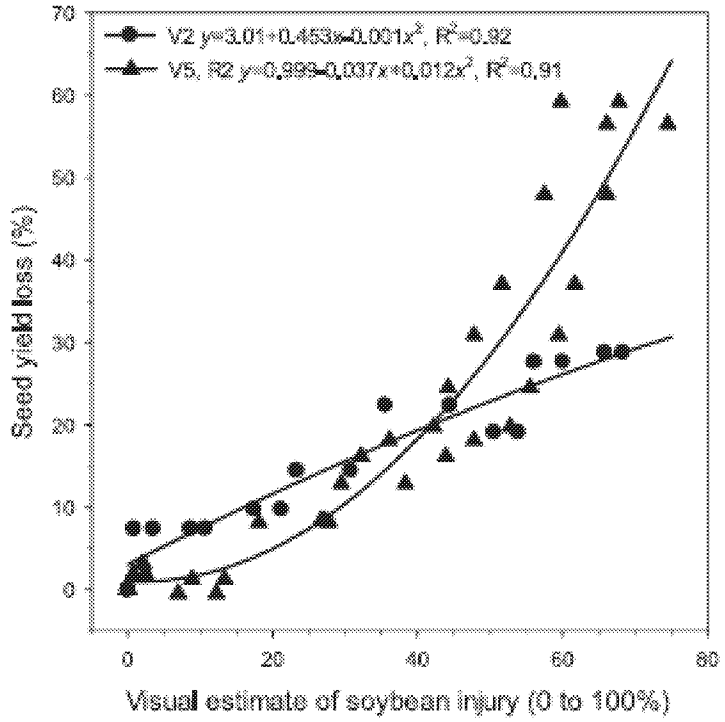

Figure 5. Relationship of visual estimates of soybean injury (0 to 100%) at 14 and 28 d after treatment and seed yield loss (%) of soybean plants treated with dicamba (0 to 22.7 g ha^{-1}) at the V2, V5, or R2 soybean growth stages. Visual estimates of injury were taken at 14 and 28 d after treatment. Studies were conducted near Lafayette, IN, in 2009 and 2010 and near Fowler, IN, in 2009. Both regressions were significant ($P < 0.0001$).

Deficiencies/Issues Related to Utility for EPA

- A randomized complete block design was used in the field; however, no details were provided about how cross-contamination was prevented among the plants in the different groups during the application phase. Furthermore, no details were provided on how cross-contamination was prevented after application given that dicamba is volatile.
- It is unclear how well the nominal application rates consistently represent relative exposure to each plant given that a backpack boom spray was used to apply the test material and no direct measurement of the application rate was provided to confirm that the rate cited in the study was accurate.
- The method description does not detail the approach taken to ensure consistency in the identification of various injury effect levels.
- It is not clear if yield differences among treatment groups reflected grain yield normalized by plant number or if it also reflected any treatment group differences in the number of plants harvested.
- The analysis did not calculate NOAEC values or ICx values.
- Raw data were not requested from the authors for this review, as a result, while regressions are possible, the statistics generated are more reflective of the central tendency of the model and not measurement or response variability.